Appendix I

SAN JOAQUIN RIVER NATIONAL WILDLIFE REFUGE

VIERRA UNIT RESTORATION PROJECT HYDRAULIC ASSESSMENT

Prepared for

River Partners

Prepared by

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PWA REF. # 1774

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1. INTRODUCTION

In partnership with the Department of Water Resources (DWR) Flood Corridor Protection Program and the San Joaquin River National Wildlife Refuge of the US Fish and Wildlife Service (USFWS), River Partners are investigating the potential to restore and enhance 511 acres of riparian vegetation and wetlands on the Vierra Unit, which is part of the West Unit of the San Joaquin River National Wildlife Refuge (Refuge). This project will enhance the floodplain corridor by supporting floodplain-compatible land use and increasing transitory floodwater storage and sediment trapping and decreasing fish entrapment hazards. Restoring riparian vegetation and wetlands on the currently fallow fields will provide benefits to riparian-obligate species including endangered and threatened species.

Philip Williams & Associates, Ltd. (PWA) have been requested by River Partners of Chico, California, to assist them in the planning and design of the Vierra Flood Protection and Environmental Enhancement Project (Vierra Project). Specifically, PWA provide here a brief qualitative engineering assessment of the anticipated changes in flood event hydraulics that will result from the proposed project, which includes manipulation and active restoration of riparian vegetation as well as minor topographic enhancement. This assessment does not include any new hydrodynamic modeling effort but refers to previous modeling undertaken for an associated project at the Refuge and past modeling efforts by the U.S. Army Corps of Engineers (USACE). PWA has relied on existing modeling results in combination with qualitative analysis to estimate the anticipated hydraulic effects of the project.

2. SUMMARY

The planned Vierra Project, encompassing both the North and South Vierra Units, at the San Joaquin River National Wildlife Refuge (Refuge) is both integral and complementary to the larger Refuge levee-breaching flood hazard reduction project (Refuge Project). The Vierra Project will include active revegetation of both the North and South Vierra Units. The larger project, initiated by the USACE after the floods of 1997 breached the San Joaquin River project levees in several locations (subsequently repaired), envisions the intentional breaching of project levees and concomitant changes in land use and land management as part of a flood hazard reduction and habitat enhancement project. While the levee breaching at the Refuge has not yet occurred, many of the land use and land management changes, including revegetation for habitat enhancement, have occurred. One of the levees that is expected to be breached as part of the Refuge Project is the levee that surrounds the South Vierra Unit. The North Vierra Unit, immediately adjacent to South Vierra, is surrounded by lower private levees that have already breached as a result of high flow events. South Vierra is therefore directly part of the Refuge Project as well as the Vierra Project; the proposed Vierra Project modifications to the North Vierra Unit will add to the flood hazard reduction and habitat enhancement benefits of the larger Refuge Project.

Significant flood hazard reduction benefits are expected to accrue as a result of both the Vierra Project and the larger Refuge Project. The most apparent such benefit will be the conversion of lands that were previously subject to damages during flood events to land uses – floodplain habitat – that directly benefit from inundation by floods. As a result of land use changes at the Vierra Unit and the adjacent parcels comprising the portion of the Refuge included in the levee-breaching project, it will no longer be necessary to protect these lands from flood hazards with project or private levees. It will also no longer be necessary to maintain the levees surrounding these lands or repair them in the event that they are breached or damaged by erosion.

In addition, the proposed Refuge Project is expected to reduce local water surface elevations during flood events. Recent USACE modeling with no assumed change in roughness levels estimated the effect of the Refuge Project to be a local 0.7 – 1.9 foot reduction in 100-year peak flow water surface elevations. However, some degree of roughness increase in the future can be expected as a result of either active or passive revegetation, topographic changes due to regrading and/or natural flood processes, and changes in flow patterns resulting from levee modifications.

The only part of the Vierra Unit currently estimated to be inundated under 100-year peak flow conditions is the North Vierra Unit, which is protected only by a private levee that is already breached in two locations. Due to the presence of the levee and the apparent hydraulic constriction provided by the Maze Road Bridge downstream, this Unit appears to provide only a limited level of flow conveyance in a large flood event. While already limited, this conveyance may be somewhat further reduced by the development of additional vegetative roughness at the project site. However, as already demonstrated at the site, revegetation will occur naturally if it does not occur through active intervention. Vegetation

recruited through natural processes is expected to contain a higher proportion of non-natives and to include the potential establishment of even higher levels of vegetative roughness due to the character of some species that are likely to establish through these processes (e.g., *Arundo donax*). Increased topographic roughness at the project site is also expected to occur in the future as a result of natural processes, whether or not active revegetation occurs. We do not expect the proposed project to ultimately produce a higher roughness value at the site than would occur with natural recruitment alone.

In addition, based on USACE estimates of local water level reductions that will result from the larger Refuge levee-breaching project (0.7 – 1.9 feet) with no assumed change in roughness levels, it is extremely unlikely that roughness values at this Unit could achieve a level that would eliminate the expected reduction in water surface elevations of the larger project. We applied a simple calculation to test the increase in roughness value that would be required to eliminate this benefit assuming a *fully active* flow area, and estimated that an increase in Manning's n from 0.04 to a value on the order of 0.20 would be required across the entire cross section to raise the water surface elevations to this extent. This is a much higher floodplain roughness than is typical of natural floodplains, especially at the higher depths of flow predicted at the North Vierra Unit.

Therefore, it is our judgment that the Vierra Project constitutes a significant flood hazard reduction project, both alone and in the context of the Refuge Project, as well as providing valuable habitat enhancement component for this reach of the San Joaquin River and floodplain. The full background on our hydraulic assessment is provided in the following sections of this document.

3. VIERRA UNIT RESTORATION AND REFUGE LEVEE-BREACHING PROJECT DESCRIPTIONS

3.1 OVERVIEW

In partnership with DWR Flood Corridor Protection Program and the USFWS, River Partners are planning the restoration and enhancement of 511 acres of riparian vegetation and wetlands on the Vierra Unit, which is part of the West Unit of the Refuge. This project will enhance flood hazard reduction goals by converting lands to floodplain-compatible uses and increasing transitory floodwater storage. By also restoring native riparian vegetation and wetlands, restoring river-floodplain connectivity, and reducing fish entrapment hazards, the project will also provide benefits to riparian-obligate species including endangered and threatened species.

The restoration of the Vierra Unit forms part of the larger Refuge restoration plan of the West Unit of the Refuge being undertaken by the USFWS. The Refuge levee breaching project includes the Lara, Hagemann and South Vierra Units. The location of both projects are identified in Figure 1.

These projects are briefly described in the following sections.

3.2 VIERRA UNIT RESTORATION PROJECT

The Vierra Unit lies on the west bank of the San Joaquin River, downstream of the confluence with the Tuolumne River and just upstream of the Highway 132 Bridge, also known as Maze Road. The North Vierra Unit is bounded by private levees to the north and east, by the USACE project levee to the south and by small berm and uplands to the west. The South Vierra Unit is bounded by the USACE project levee to the north, south and east and by uplands to the west.

Restoration of the Vierra Unit consists largely of revegetation of native species. It does not involve any substantial earth moving operations or new breaches of either private or USACE project levees. The preliminary planting plan proposed by River Partners for the 511-acre Vierra North Property consists of several different zones, mapped in Figure 2.

- *Restoration* areas will include two different vegetation groupings: the *buttonbush association* will form a 100 to 300 feet band around the perimeter of the wetland basins, and the *Fremont cottonwood association* will be planted in the remaining acreage of the restoration area. The planting density will be 227 plants per acre. The site currently supports many Fremont cottonwood and black willow saplings dating from flooding in 1997, which will be flagged and incorporated in restoration plantings.

- *Enhancement* areas currently have some natural recruitment, but will be augmented to add species diversity, planted at a density of 75 plants per acre.
- *Shrub clusters* will cover approximately 25 acres of the site and will be planted with double density shrubs.
- The *Hetch Hetchy Line* is a narrow strip running along the Hetch Hetchy aqueduct, bisecting the site. This will consist of native grasses with no woody species.
- *Wetland* areas will be scraped to a maximum depth of 18 inches, and wetland water control structures will be installed.
- A *herbaceous understory* will be planted on 40% to 50% of the restoration and enhancement areas.

The species composition of each planting grouping is given in Table 1.

Table 1 – Vegetation species included in each planting group

Buttonbush Association	**Freemont Cottonwood Association**	**Enhancement**	**Shrub Cluster**	**Herbaceous Understory**
Black willow Blackberry Buttonbush Fremont Cottonwood Oregon ash	Arroyo willow Black willow Blackberry Box elder California rose Coyote brush Elderberry Fremont cottonwood Oregon ash Sandbar willow Valley oak	Blackberry California rose Coyote brush Elderberry Valley oak	Arroyo willow Blackberry California rose Coyote brush Elderberry Sandbar willow	Mugwort Gumplant Creeping wildrye native grass

3.3 REFUGE LEVEE-BREACHING PROJECT

The larger Refuge levee breaching project was initiated as a result of the January 1997 flood when several levees failed along the west side of the San Joaquin River in the vicinity of the Tuolumne River confluence. After the flood, the levees were repaired; however, the Refuge worked with the USACE to plan a non-structural flood management alternative (NSA) to reduce future flood hazards along this reach, which was subject to flood failure. A significant element of this flood management alternative included land management for flooding-compatible uses. The alternative included breaching existing mainstem San Joaquin River levees on recently-acquired Refuge land to protect and restore wetland and riparian habitat as shown in Figure 1. The proposed NSA will provide floodplain inundation behind project levees

of up to 3,200 acres of the Refuge land in some years. PWA worked with the Refuge staff to develop a modified levee breaching plan. The levee breaching plan has not yet been finalized by the USFWS subsequent to the recommendations made by PWA (PWA, 2004).

3.4 LINKAGE BETWEEN THE VIERRA AND LARGER REFUGE LEVEE-BREACHING PROJECT

The North Vierra Unit is an integral part of the phased approach for restoration of the whole Refuge that includes breaching of the project levees surrounding the South Vierra, Lara and Hagemann Units. The North Vierra Unit will provide conveyance of flows back into the San Joaquin River when the project levees in Lara, Hageman and Vierra are breached.

These two projects will collectively provide substantial flood benefits, in large part as a result of conversion of lands to flood-compatible uses, removing the need for flood hazard protection and largely eliminating the risk of flood damages. The Refuge levee-breaching project will additionally provide increased conveyance and a small amount of transitory storage. The USACE has estimated that the reduction in water surface elevation through the North Vierra Unit at approximately 0.7 - 1.9 feet for the 100-year event.

Additional flood benefits of the North Vierra project include provision of a degree of improved flood conveyance at lower flood flows through maintenance of existing breaches in the private levees and wind-wave and flood flow erosion protection of floodplain lands as a result of revegetation. Fetch lengths across the Unit are substantial and riparian vegetation will reduce these fetch lengths, therefore reducing potential erosive forces due to wave action.

4. FLOOD HAZARD SETTING

These two projects in the West Unit of the San Joaquin River National Wildlife Refuge are located along a reach of the San Joaquin River that is particularly well-suited to a levee-breaching and land use conversion flood management project.

The reach is marked by a complex of sloughs and abandoned channels and is immediately opposite the confluence with a major San Joaquin River tributary, the Tuolumne River. This complexity creates a turbulent flow regime during flood events, particularly during the rising and falling limbs of a flood hydrograph. Such turbulence makes the area particularly susceptible to levee erosion and damage, and ultimately, levee failure.

The active river channel is crossed immediately downstream of the site by the Maze Road Bridge. It is quite likely that this structure constricts the river during high flow events, slowing the water upstream. This backwater condition would create fairly slow velocities across the reach immediately upstream, or the North Vierra Unit, minimizing the effect of new floodplain vegetation and surface irregularities on water surface elevations in this reach during high flow events.

Lastly, the presence of a distinct grade break at the edge of the floodplain will limit the extent of flood flows passing through levee breaches and inundating the floodplain.

5. FUTURE FLOOD CONDITIONS ASSESSMENT

While the larger combination of projects referred to as the Vierra and Refuge levee-breaching projects are recognized to have significant benefits in terms of conversion to flood-compatible land uses, we recognize that the revegetation elements of these projects may have the potential to reduce expected flood benefits in terms of water surface lowering through creation of vegetative "roughness," or a higher "Manning's n" value for hydraulic purposes. In this analysis, we specifically examined the potential of revegetation efforts at the Vierra site to increase water surface elevations during flood events.

PWA used qualitative assessment techniques to evaluate the expected impacts of roughness changes at this site on flood event hydraulics. Nonetheless, we benefited from prior quantitative analyses in the form of hydrodynamic modeling results provided by the USACE (a 100-year flood event) and a past PWA study (PWA 2004) of this reach of the San Joaquin River, which investigated a small flood event (approximately a 10-year event). PWA also reviewed the 1955 Design Profile used by the USACE in the design of the project levees in this reach, which represents the estimated water surface profile for the design flow for the project levees (approximately a 60-year event).

5.1 CURRENT SITE MANNING'S N

Information supplied from previous landowners indicates the Vierra Unit was first farmed as a dryland grain ranch. In 1918 and 1919 five dryland grain ranches were combined into "El Solyo" and a more diversified farming operation was carried out, including orchard and row crops. This has been the dominant land use since the early 1900s. The Vierra Unit has not been farmed since the 1997 flood, and without farming the field is dominated by vigorous weeds such as bull thistle, annual grasses, fiddleneck, filaree, telegraphweed, stinging nettle, pampas grass, Johnson grass, perennial pepperweed, prickly lettuce and milk thistle (Sperber T., 2005, pers. comm., 4th May). Some herbaceous native species can also be found scattered throughout the site. Flooding during 1997 and 1998 allowed seedlings and saplings to develop of many former agricultural fields, although by January 2002 most were dead due to competition from weeds and herbivory from voles. Some Fremont cottonwood and black willow saplings have survived and will be incorporated into the restoration plantings. Additionally, California rose and California blackberry plants are scattered along the levee sides. The current Manning's n value for the site based on this information in addition to various aerial photographs acquired for the site (for examples, see Figures 3 and 4) was estimated to be between 0.04 and 0.06 using standard tables (e.g., Chow, 1959) and engineering judgment.

5.2 SUMMARY OF RELATED STUDIES

The following section provides details of recent studies by PWA and the USACE with relevance to flood issues for this project.

5.2.1 San Joaquin River National Wildlife Refuge-Phase 2: PWA MIKE FLOOD analysis

The focus of this study by PWA, completed in April 2004, was to assess opportunities to improve habitat benefits for restoration of the floodplain Units of the Refuge for anadromous fish through a revised levee-breaching scenario. A two-dimensional hydrodynamic model, MIKE 21, was used to predict inundation frequency, area, duration, timing, and depth during about a 10-year flood on the floodplain Units, which include the Lara, Hagemann, and South Vierra properties. The modeling was not designed to address flood benefits of the whole restoration project. However, the model results were assessed to provide an indication of the reduction of water surface elevation in the San Joaquin River through the project reach. The hydrodynamic modeling results of this study indicated that, for approximately a 10-year return period flow in the San Joaquin River (almost 34,000 cfs), the reduction in water surface elevation as a result of breaching of the USACE project levees in the Lara, Hagemann, and South Vierra Units could be up to 0.3 feet. It is possible that for larger flows this reduction in water surface elevation could be greater than 0.3 feet. However, larger flows were not modeled as part of this study.

According to the two-dimensional model used for this study, flow begins to break out onto the floodplain of the North Vierra Unit through two existing relatively small breaches through the private levee at approximately 11,000 cfs, approximately the 2- to 3-year event in the San Joaquin River.

5.2.2 USACE UNET and Flo2D Modeling Results

As part of the USACE's Sacramento-San Joaquin Rivers Comprehensive Study undertaken in recent years, the USACE have modeled this study reach of the San Joaquin River in the one-dimensional UNET hydrodynamic model and the two-dimensional Flo2D model. Specific results for the 100-year event modeled by the USACE (71,800 cfs at North Vierra) using these two methods are described as follows.

The North Vierra Unit extends through the floodplain adjacent to the San Joaquin River between UNET River Miles 75 and 79, as shown by Figure 5. Using UNET the USACE modeled the 100-year event with and without the breaches in the project levees of the Refuge (i.e. the levee that surrounds the Lara, Hagemann, and South Vierra Units). The water surface elevation for the 100-year event, without levee breaches, ranged from 40.78 feet NGVD (all vertical elevations in NGVD) at River Mile 75.19 to 41.75 feet at River Mile 78.97. The project levees, including the levees of the South Vierra, were not shown as

overtopped during the modeled event and were therefore considered outside of the flood zone in this scenario. For the 100-year event, with levee breaches, the water surface elevation ranged from 38.93 feet NGVD at River Mile 75.19 to 41.08 feet NGVD at River Mile 78.97. This represents a reduction in water surface elevation as a result of breaching the project levees of 1.85 feet at River Mile 75.19 (just upstream of Maze Road Bridge) to 0.67 feet at River Mile 78.97 (approximately adjacent to the upstream extent of the North Vierra Unit.

Average velocities were not computed through this study reach using UNET for the purposes of the Comprehensive Study. In addition the North Vierra Unit was modeled as a storage area in the UNET model, as opposed to a conveyance area, and therefore relied on no estimate of Manning's n and produced no depth or flow data for the floodplain area of the North Vierra Unit.

The study reach was also modeled for the Comprehensive Study by the USACE using the Flo2D model. However, the grid cell resolution of this model domain was 2000 feet, and therefore the results presented by the USACE are very approximate. The model domain for the study reach is shown by Figure 6. Corresponding depths and water surface elevations for the 100-year event are given in Figure 7. Due to the coarse nature of the grid cell resolution in the Flo2D model, we consider that the water surface elevation results provided by the UNET model are probably more representative of the flow condition than those provided by Figure 7 for the Flo2D simulation. Figure 8 shows the corresponding average velocities predicted using Flo2D. In the absence of any better data, average floodplain velocities through the floodplain of the North Vierra Unit were predicted by Flo2D at less than 1 foot/second for the 100-year event.

The model results are consistent with Maze Road Bridge acting as a constriction to flows passing downstream in the San Joaquin River. The low velocities on the North Vierra Unit predicted by the hydraulic models are likely indicative of the backwater effects that would result from such a constriction, as well as the partial blockage created by the private levees. Low velocities on the floodplain of the North Vierra Unit will tend to limit the influence of vegetation on hydraulic losses, or reduce the effect of Manning's n on the water surface profile.

For all of the Flo2D model nodes in the vicinity of the North Vierra site, the USACE used a Manning's n of 0.08 to represent existing roughness of the floodplain area.

5.2.3 1955 USACE levee design flood profile

Figure 9 shows the 1955 project levee design flood profile obtained from the USACE. In the vicinity of the North Vierra Unit the water surface elevation calculated in 1955 for the 46,000 cfs event was approximately 37 feet, 2 to 3 feet lower than the 100-year peak flow water surface elevation predicted by

the UNET model. This 46,000 cfs event represents approximately a 60-year peak flow event based on current flow-frequency relationships.

5.3 FUTURE MANNING'S N

Over time, the vegetative roughness at this site, including the North Vierra Unit, will increase whether or not active revegetation occurs. Natural recruitment at the site has already begun. One hazard of natural recruitment is its tendency to include significant levels of non-native vegetation. While active revegetation may or may not limit vegetative roughness beyond what would tend to occur over time under natural recruitment, from a restoration perspective, a predominance of native vegetation is certainly preferable. Non-natives established through natural recruitment in the absence of active planting sometimes include dense stands of certain species with very high roughness values. Active revegetation of the Units is expected to establish vegetation at the site more rapidly than would natural recruitment, and to result in a higher proportion of native vegetation than would natural recruitment alone. Active revegetation will also tend to limit the establishment of non-native vegetation.

Either active or passive revegetation of re-connected floodplain at Refuge, including the North Vierra Unit, is expected to significantly increase the Manning's n value compared to that associated with recent agricultural use of the site. The significant depths of flow at North Vierra in a 100-year flood event would bend over or wash out non-woody vegetation, creating a very low floodplain n of 0.04 – 0.06. With riparian vegetation in place however, n-values are expected to reach a value in the range of 0.08 – 0.20. Even with deeper flood flows, woody vegetation creates strong resistance; the drag caused by trunks and branches is substantial. Typical Manning's n values calibrated and used for floodplains with dense riparian vegetation are within the range 0.10 – 0.15 (see Arcement and Schneider, 1989). It is uncertain whether passive revegetation would result in a higher Manning's n than active revegetation; the resulting value may be similar. Thus, failure to implement the revegetation project would not be expected to reduce the probability of a significant increase in Manning's n.

5.4 POTENTIAL FOR FUTURE MANNING'S N TO AFFECT FLOOD HAZARDS

Manning's equation calculations were used to assess the potential implications of the estimated increase in Manning's n as a result of the proposed planting plan on the 100-year flow water surface elevation on the floodplain of the North Vierra Unit. Based on USACE estimates of local water level reductions that will result from the larger Refuge levee-breaching project (0.7 – 1.9 feet) with no assumed change in roughness levels, it is extremely unlikely that roughness values at this Unit could achieve a level that would eliminate the expected reduction in water surface elevations of the larger project. However, we applied this simple calculation to test the increase in roughness value that would be required to eliminate this benefit assuming a *fully active* flow area (which does not appear to exist), and estimated that an

increase in Manning's n from 0.04 to a value on the order of 0.20 would be required across the entire cross section to raise the water surface elevations to this extent. This is a much higher floodplain roughness than is typical of natural floodplains, especially at the higher depths of flow predicted at the North Vierra Unit.

6. POTENTIALLY-AFFECTED STRUCTURES ADJACENT TO THE VIERRA UNIT

An evaluation was made of the relationship of levee heights to nearby structures that might be affected by a change in water surface elevations at the Vierra Unit. The top (crest) of the private levee that surrounds the North Vierra Unit is at an elevation of approximately 32 feet. It is breached at the southerly and northerly extents. Two existing structures are located adjacent to the North Vierra Unit. The land adjacent to these structures is at elevation of approximately 33.1 feet for one structure and approximately 34.2 feet for the other, or about 1 - 2 feet above the top of the private levee. The top of the project levee surrounding the South Vierra Unit and forming a southern boundary to the North Vierra Unit is at an elevation of approximately 41 feet.

Based on this information, which was generated from the USACE's digital terrain model (DTM) for the area, personal communication with Scott Stonestreet of the USACE, Sacramento District, and the modeling results provided in the previous sections, several conclusions have been drawn. First, for both the modeled 100-year and the calculated 1955 design event, the project levee surrounding the South Vierra Unit is not overtopped. This area can therefore be considered to be outside the floodplain in terms of the 100-year event without the Refuge levee-breaching project implemented. Second, both the private levee and the land adjacent to nearby structures are significantly overtopped by both the estimated 60- and 100-year flow events, whether or not the Refuge levee-breaching project is implemented. For the modeled 100-year event the private levee surrounding the North Vierra Unit will be overtopped by approximately 8 to 9 feet without the Refuge levee-breaching project. For the calculated 1955 design flow the private levee surrounding the North Vierra Unit will be overtopped by approximately 5 feet. Therefore, for both the 100-year and 1955 design event, these structures will likely be flooded to significant depths. The land surrounding the structures adjacent to the North Vierra Unit will probably be inundated by approximately 3 to 4 feet as calculated for the 1955 design event and approximately 5 to 8 feet as estimated for the 100-year event without the Refuge levee-breaching project. With the Refuge levee-breaching project, water surface elevations may be reduced by approximately 0.7 to 1.9 feet at the 100-year flood event based on modeling by the USACE. Thus, the North Vierra Unit and the nearby structures will probably still be significantly inundated during a 60-year or larger flood event with the Refuge levee-breaching project in place.

4. SUGGESTED DESIGN MODIFICATIONS FOR THE VIERRA PROJECT

Based on the findings listed in the previous sections, the South Vierra Unit is not within the 100-year floodplain because the flows at this magnitude do not overtop the project levee. Therefore, riparian restoration plans by RP in this Unit will not impact flood conveyance for the 100-year event. However, since the North Vierra Unit private levees are overtopped at the 100-year event, this Unit is at least a storage area and may also have some conveyance potential. An increase in roughness in the North Vierra Unit may reduce conveyance of flood flows and/or increase the water surface elevation during large flood events. In this section we provide some suggestions for modifications to the present restoration plan proposed by River Partners to reduce impacts to floodplain roughness while maintaining the thrust of the plan.

As previously described, the complete Refuge levee-breaching project will provide significant reduction in water surface elevations in the San Joaquin River for the 100-year event (locally up to 1.9 feet). However, some of this expected flood benefit, in terms of reduction of water surface elevation during the 100-year event, may be lost due to the increase in floodplain roughness resulting from natural recruitment over time or the proposed riparian restoration project proposed in the North Vierra Unit by RP.

The probability of an increase in flood flow water surface elevation due to the proposed restoration plan may be minimized by reducing roughness through primary flow paths: for example, by providing designed flow paths through the site, and reducing the amount of dense and woody vegetation through the primary flow paths. Further details are given below.

We suggest the following modifications to the preliminary planting plan (see Figure 10) to minimize reductions in the flood benefits provided by the Refuge levee-breaching project:

1. Areas 1 and 2 shown in Figure 10 lie in the flow path of the San Joaquin River and, according to Figures 3 and 4, are presently of relatively lower roughness (n = 0.04 to 0.08) than the roughness represented by the preliminary planting plans. However, it is expected that natural recruitment of vegetation will occur, which may include dense stands of non-native vegetation. Such a condition could represent very high roughness in future years. The proposed revegetation project is expected to significantly reduce the recruitment of non-native vegetation (personal communication with Dan Efseaff of RP). We would therefore recommend that the planting plan be modified to include low density vegetation in Areas 1 and 2, possibly native grasses, or vegetation that has low resistance to flow (i.e. bends over easily). Planting these areas with such species of vegetation may inhibit the natural recruitment of dense vegetation. We estimate that the roughness of these areas may only be slightly increased to n = 0.08 to 0.1 under this revised planting plan.

2. Area 3 (the South Vierra Unit) can be planted using the present vegetation plans as this area is not flooded during a 100-year flow event.

3. The planting plan for Area 4 (North Vierra Unit) should be modified as shown in Figure 10. The predominant flood flow path is shown in this figure through the North Vierra Unit. We propose low-density vegetation of relatively lower roughness in comparison to the present planting plan should be implemented through this floodway, similar to Areas 1 and 2. Vegetation that bends over less easily might be planted between (adjacent to) this floodway and the San Joaquin River, orientated longitudinally to the predominant flood flow path, rather than transversely to the predominant flood flow path.

4. The wetland in the North Vierra Unit may provide a low-roughness exit route for flows leaving South Vierra under future Refuge levee breaching plans and should be expanded if it is expected to remain primarily in open water, without large stands of stiff emergent vegetation. This increase in wetland area will also facilitate flood flows across the unit from the San Joaquin River.

5. A strip of dense woody vegetation, at the margin of the active flow zone, could be added to the west of the proposed wetland area to assist in diverting flows back into the flow contraction zone just upstream of the Maze Road Bridge. This strip of vegetation would also provide some increased level of protection to the properties adjacent to the North Vierra Unit.

6. An area of dense woody vegetation could be planted to the west of the flow expansion line shown in Figure 10. This area could be considered to be out of the floodway since expansion effects will be present downstream of the project levee surrounding the South Vierra Unit, minimizing the efficiency of the zone to the west of this line to convey flood flows. This expansion line should be positioned based on the generally-accepted 2:1 expansion ratio.

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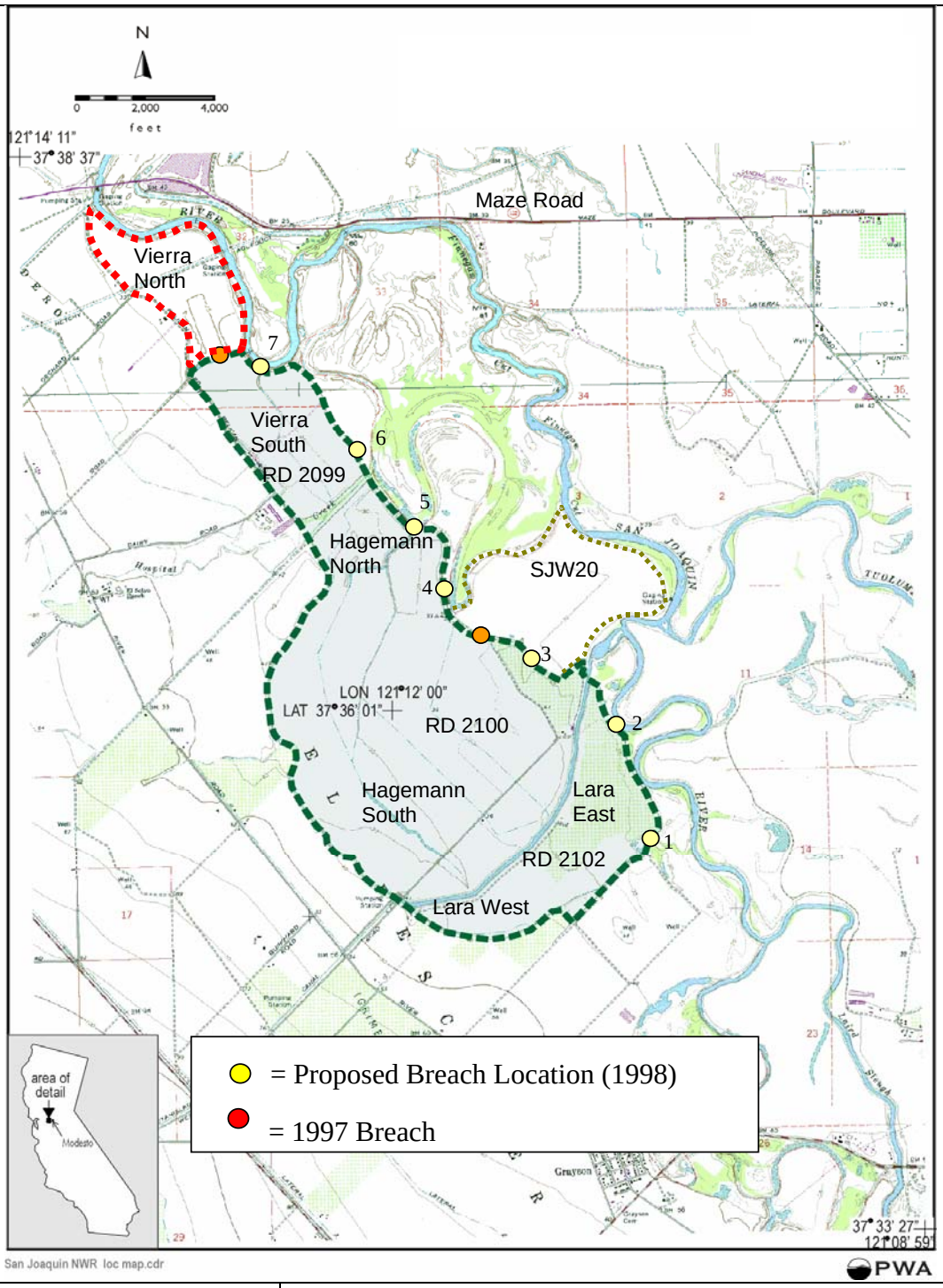

figure 1

SJR National Wildlife Refuge Vierra North Hydraulic Assessment

Map of West Unit of Refuge

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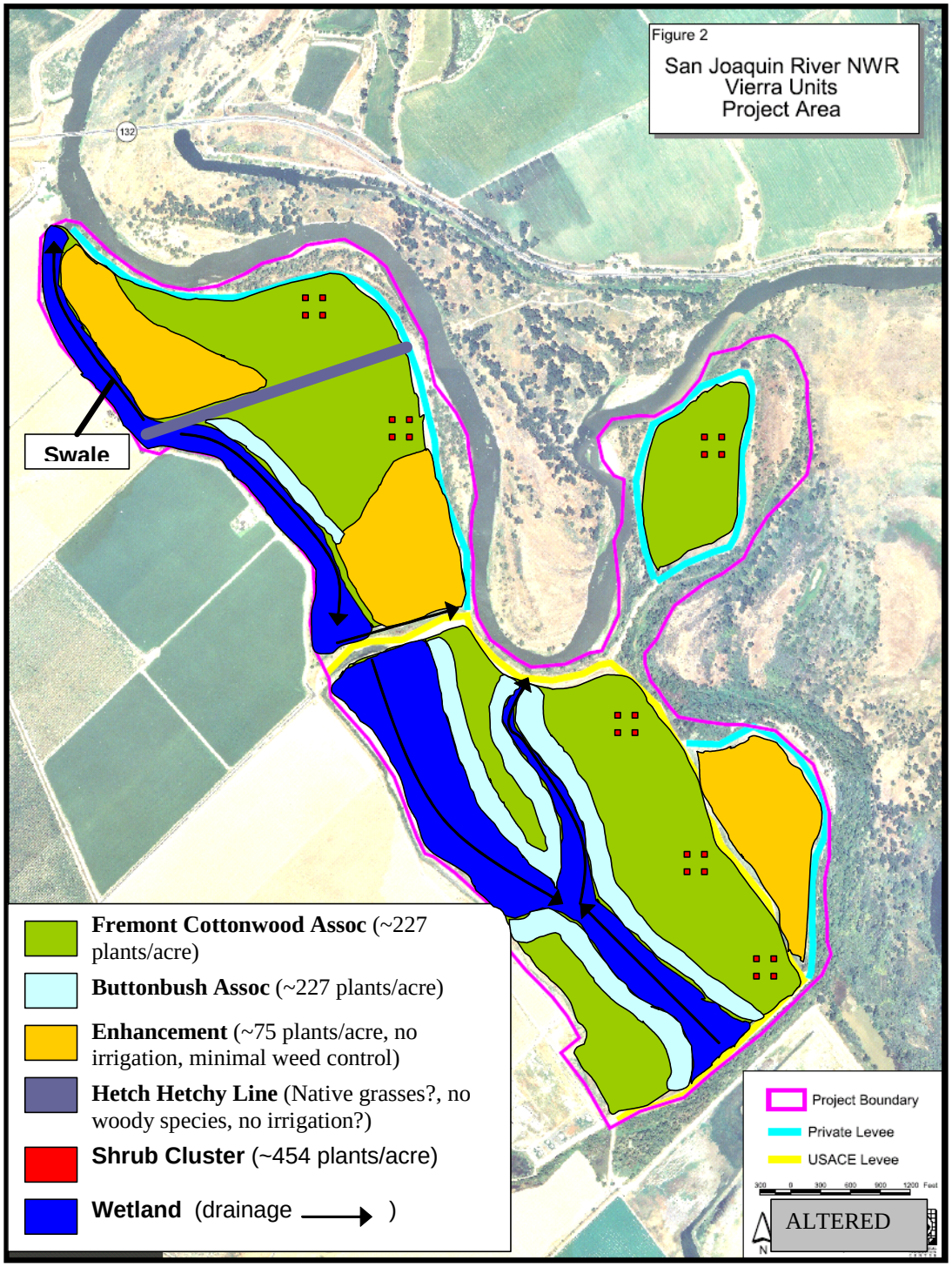


Source: River Partners (2005)

figure 2

SJR National Wildlife Refuge Vierra North Hydraulic Assessment

River Partners Preliminary Planting Plan

PWA Ref 1774

PWA

Source: Tamara Sperber, River Partners, May 2005
Looking to the south east over the northern section of Vierra North

figure 3
SJR National Wildlife Refuge Vierra North Hydraulic Assessment

Aerial Photograph of North Section of Vierra Property

PWA Ref 1774

PWA

P:\Projects\1774_SJR_Vierra_Restoration\Memo\Figures\Fig3&4_Aerial_photos.doc

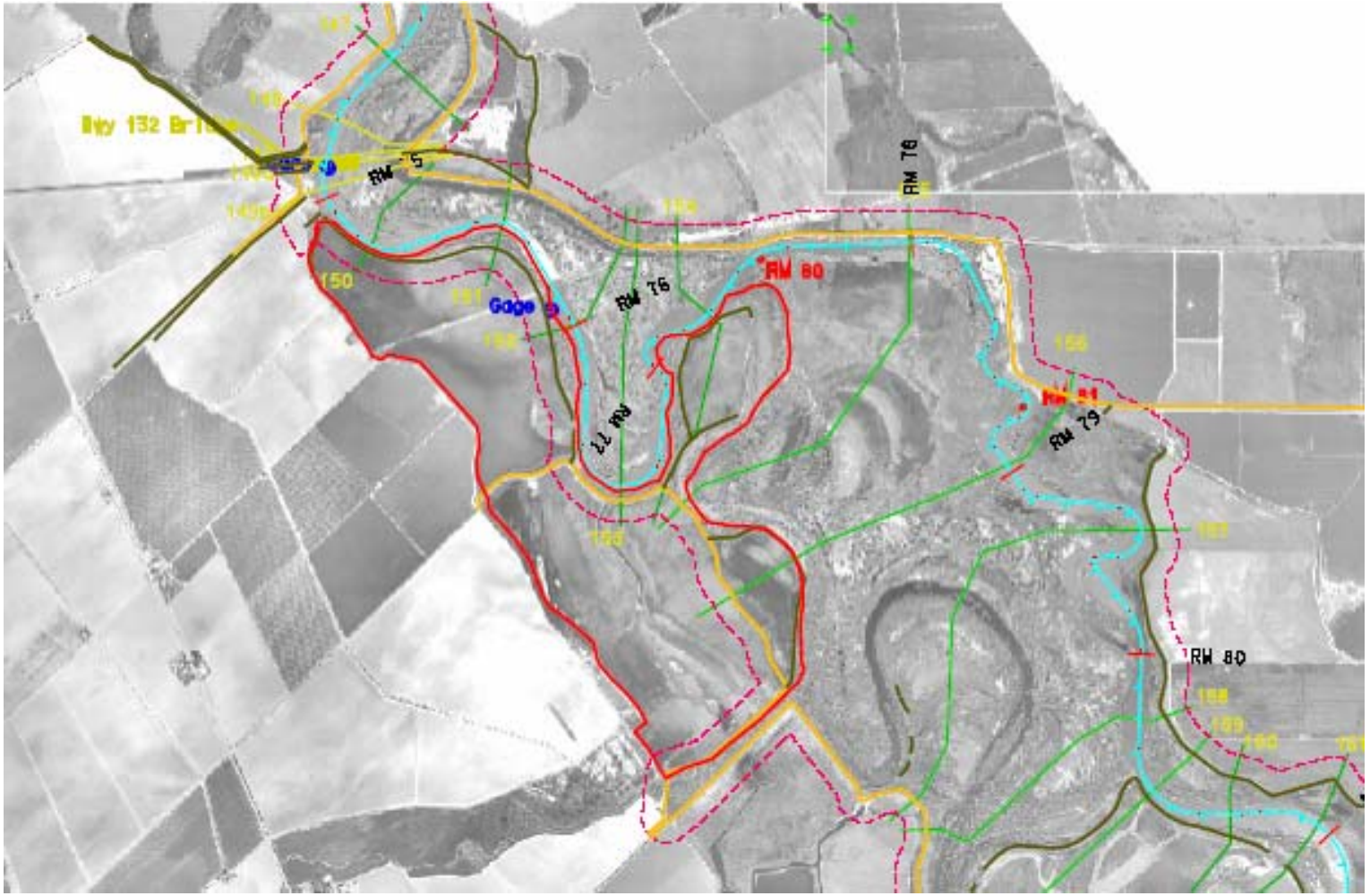
Source: Tamara Sperber, River Partners, May 2005
Looking to the south east over the southern section of Vierra North

figure 4
SJR National Wildlife Refuge Vierra North Hydraulic Assessment

Aerial Photograph of South Section of Vierra Property

PWA Ref 1774

PWA



Source: USACE

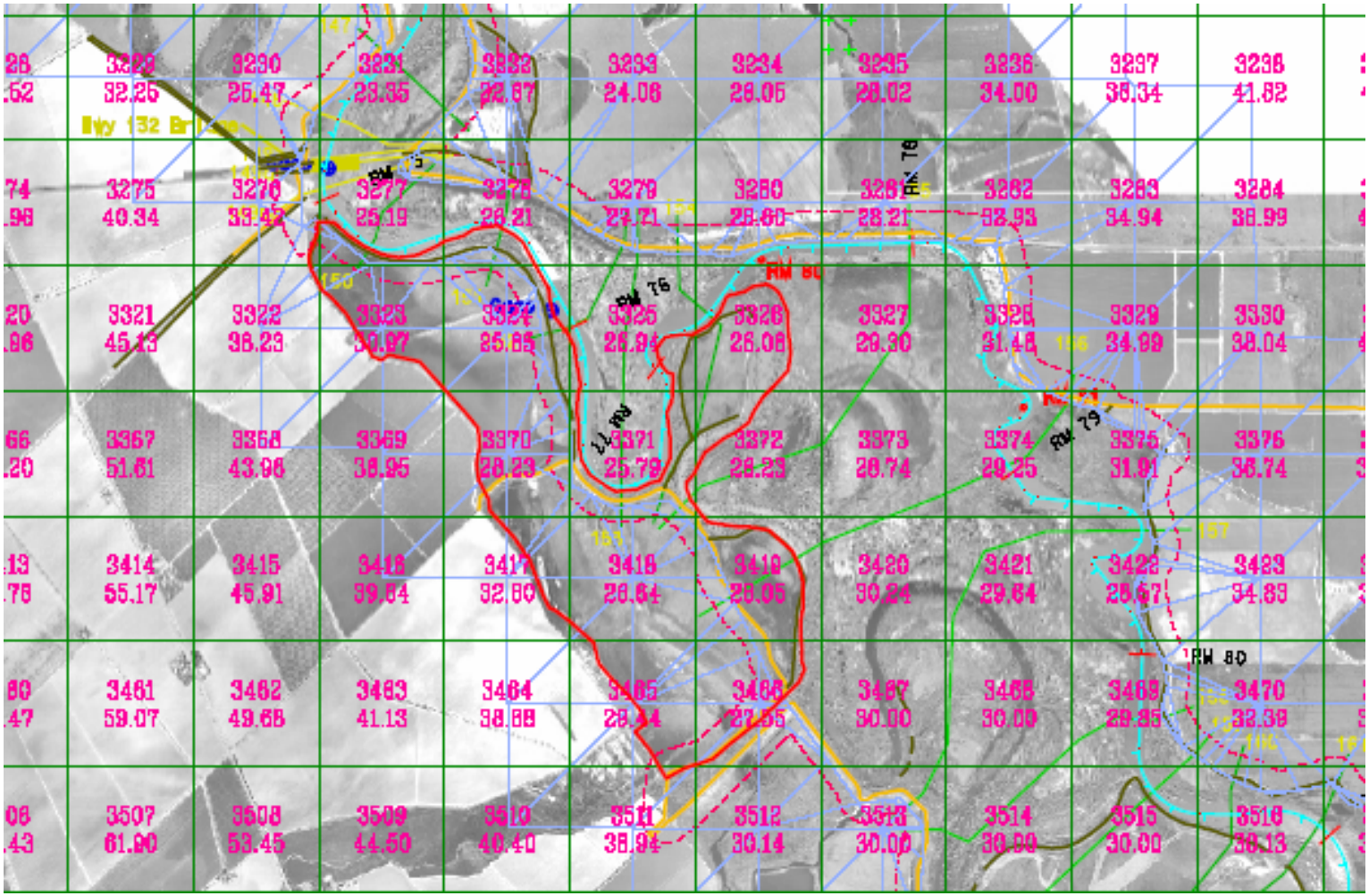
figure 5
SJR National Wildlife Refuge Vierra North Hydraulic Assessment

UNET Model Stationing

PWA Ref 1774

PWA

P:\Projects\1774_SJR_Vierra_Restoration\Memo\Figures\Fig5_UNET_model_stationing.doc



Source: USACE

figure 6
SJR National Wildlife Refuge Vierra North Hydraulic Assessment

Flo2D Grid/Node Numbering

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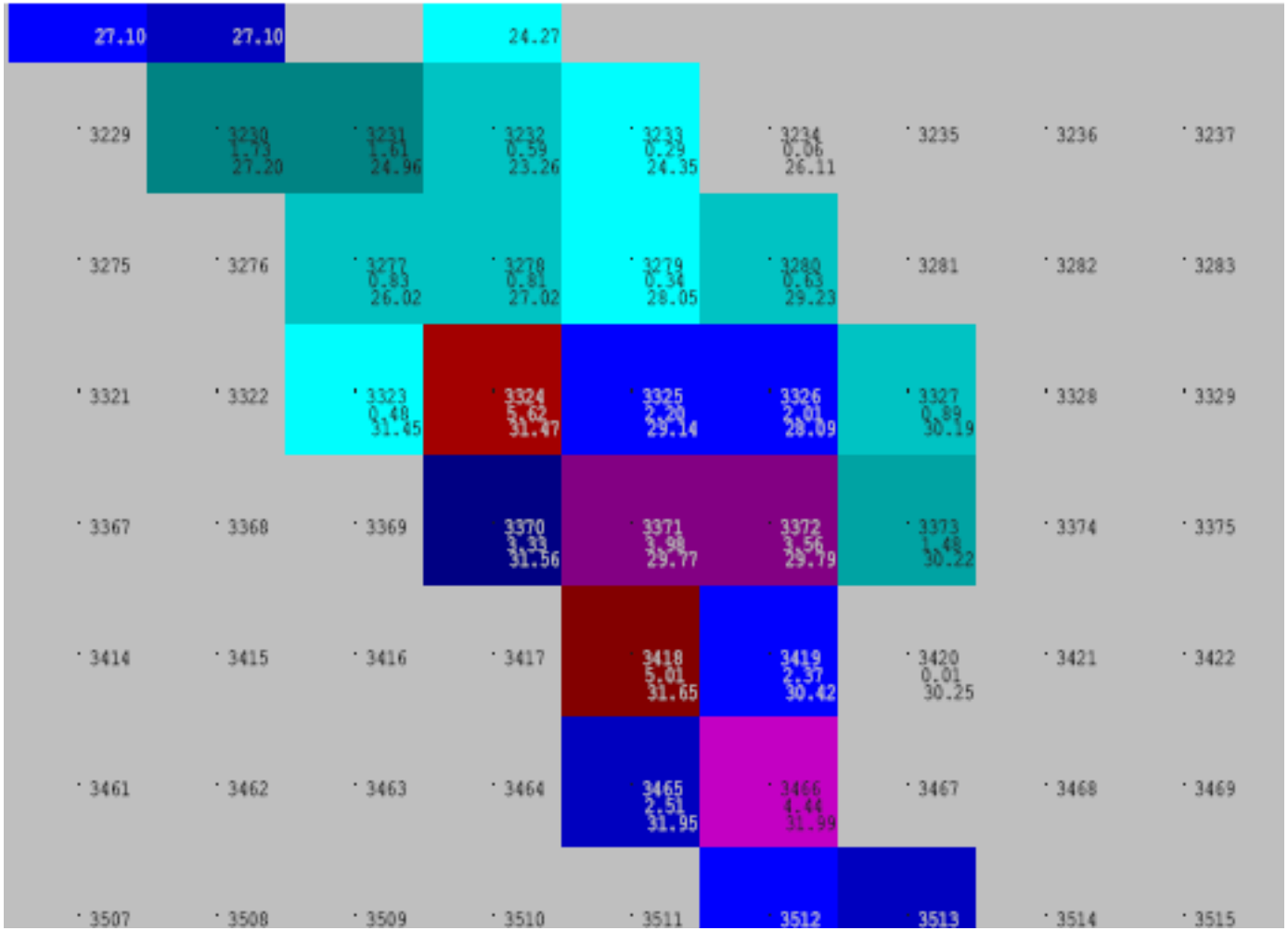
PWA

P:\Projects\1774_SJR_Vierra_Restoration\Memo\Figures\Fig6_Fl2D_Grid_Node.doc



Source: USACE

figure 7

SJR National Wildlife Refuge Vierra North Hydraulic Assessment

Flo2D Depth and Water Surface Elevation

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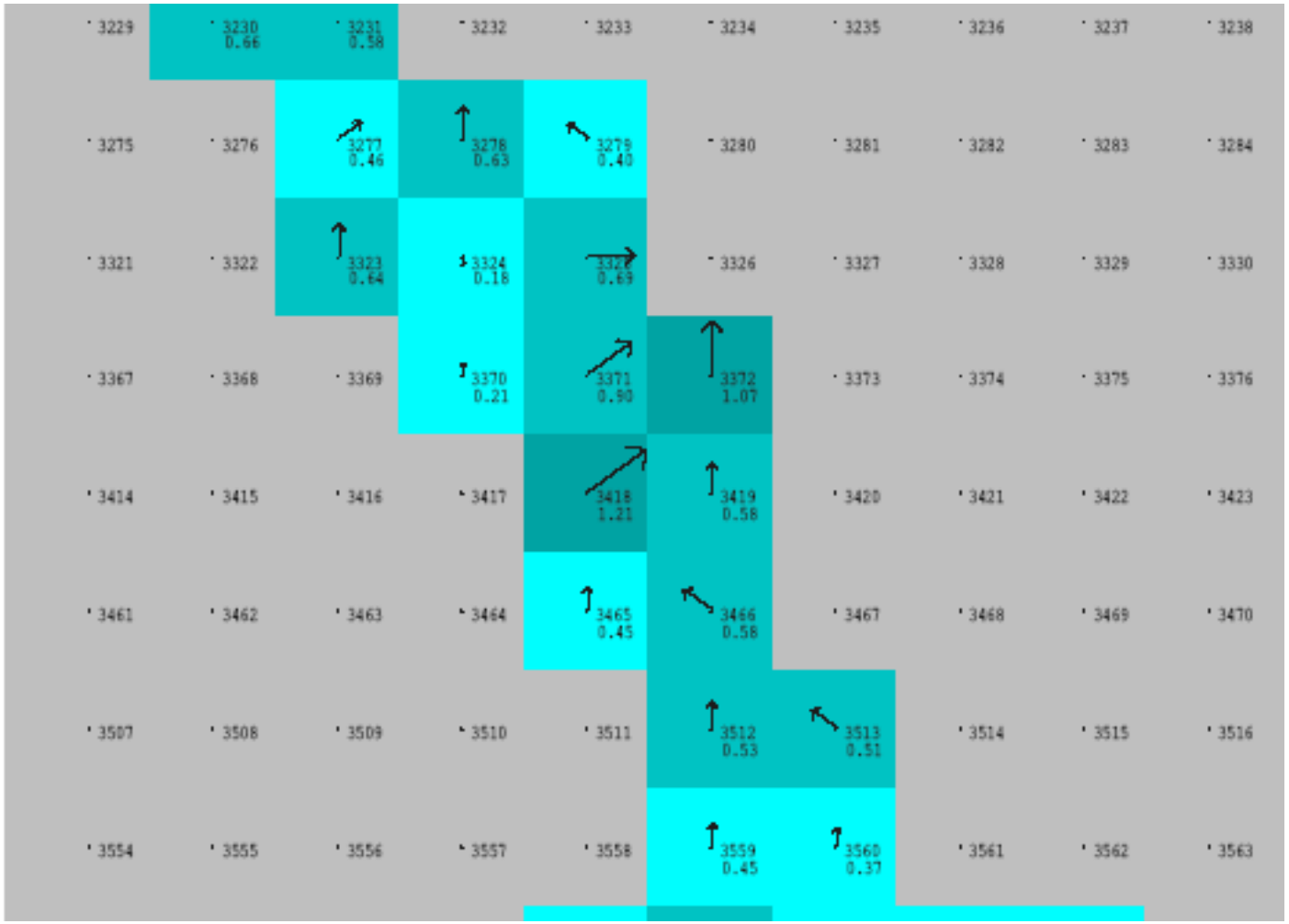
PWA

P:\Projects\1774_SJR_Vierra_Restoration\Memo\Figures\Fig7_Fl2D_Depths_WSE.doc



Source: USACE

figure 8

SJR National Wildlife Refuge Vierra North Hydraulic Assessment

Flo2D Average Velocities

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PWA

P:\Projects\1774_SJR_Vierra_Restoration\Memo\Figures\Fig8_Fl2D_Av_vel.doc

CORPS OF ENGINEERS

U. S. ARMY

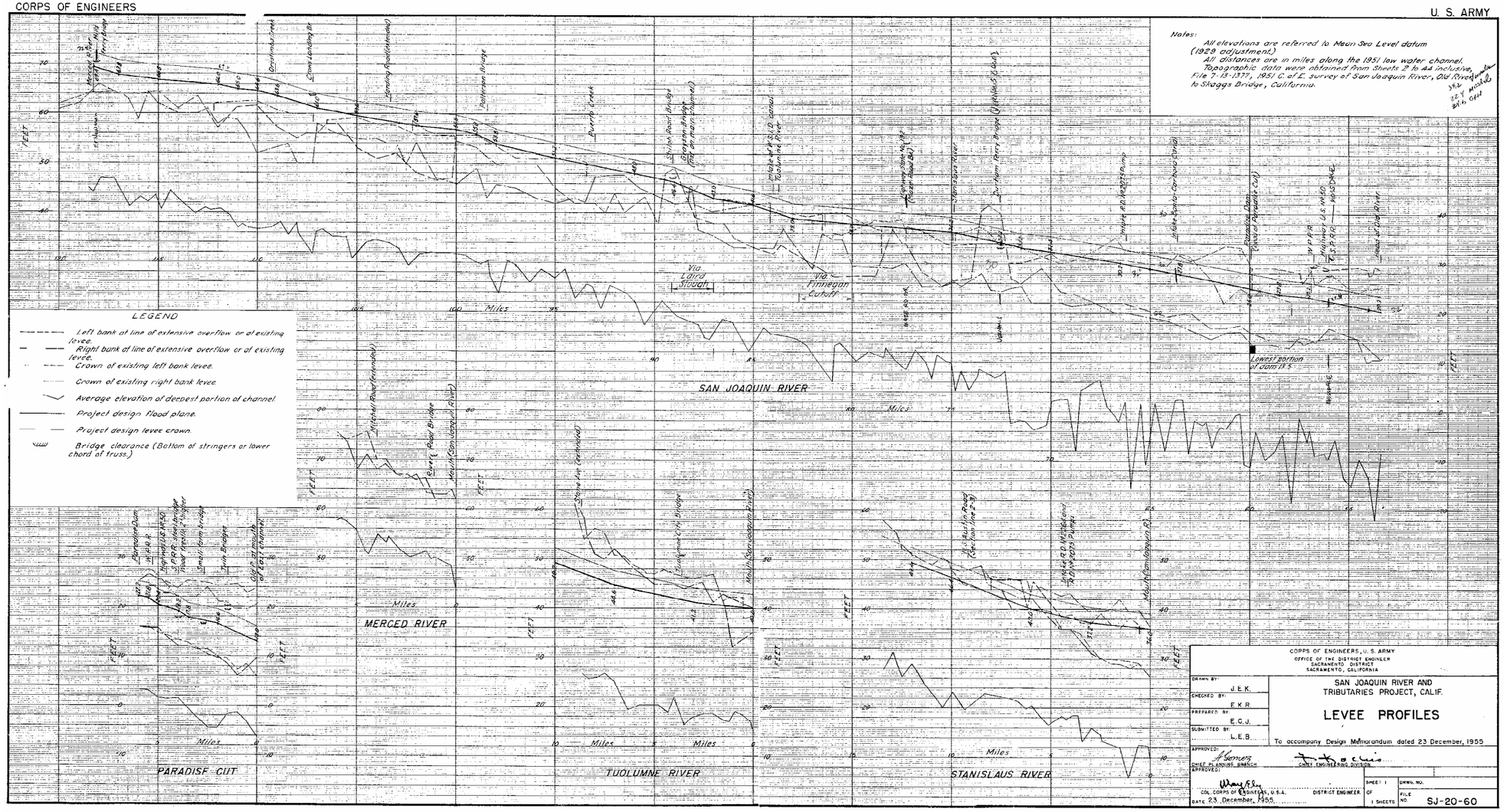

figure 9

SJR National Wildlife Refuge Vierra North Hydraulic Assessment

1955 Design Profile

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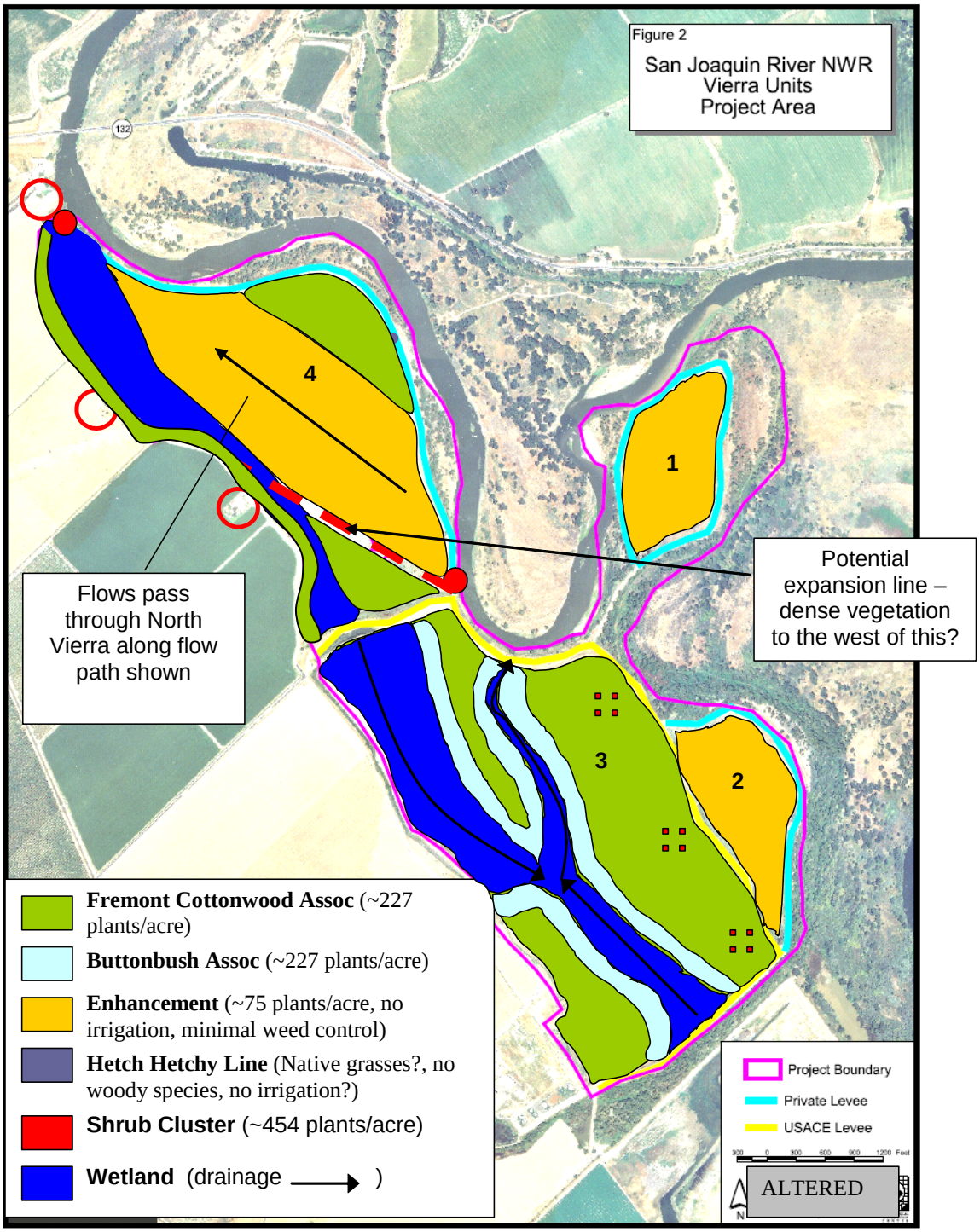
PWA



Source: River Partners (2005)

figure 10

SJR National Wildlife Refuge Vierra North Hydraulic ssessment

Modifications to River Partners Preliminary Planting Plan

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PWA

P:\Projects\1774_SJR_Vierra_Restoration\Memo\Figures\Fig10_mods_to_planting_plan.doc